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PUBLISHERS' NOTICE

Due to war-time difficulties of production, for the remainder of the period of the war this journal will be published in alternate months, starting January, 1944, instead of monthly as in the past.

Tests on Grinding Aids.

A SERIES of tests to ascertain the effect of Vinsol resin, cod oil, beef tallow, Nopco 1900, Nopco Plastol No. 1, kojec acid, aluminium stearate, and powdered aluminium on the rate of grinding Portland cement clinker, and on the effect of these additions on the strength of concrete, has been made by Professor E. R. Dawley at the Kansas State College. In a report on the results, it is stated that one brand of clinker used for normal Portland cement was used for all the tests. The quantity of grinding aid used was 0·07 per cent. in every case. The grinding was done in a small laboratory mill; 50 lb. of clinker were ground at one time. The fineness was determined by a Wagner turbidimeter. Three and one-half per cent. of gypsum was included in all the cements except one. The effectiveness of a given grinding aid was measured by the number of revolutions of the mill necessary to increase the specific surface from 800 to 1,800 square centimetres per gramme. A curve was plotted to obtain this number. By adding 700 revolutions to this number the approximate total number of revolutions required to produce a surface area of 1,800 was obtained.

Table I shows the cement-grinding data. The grinding aids are here listed in the order of decreasing effectiveness. The blank grind contained 3·5 per cent. of gypsum, but no grinding aid; each of the other cements was compared with this one. Two of the cements, one with powdered aluminium and the other with no gypsum, required more mill revolutions than the blank to produce 1,800 specific surface. This indicates that perhaps gypsum could also be listed as an aid in grinding, while powdered aluminium is a detriment. Vinsol resin is seen to be the

TABLE I.—GRINDING DATA.

Grinding Aid	Final Surface Area of Cement sq. cm. per g.	Revolutions Necessary to Increase Surface Area from 800 to 1,800 sq. cm. per g.	Calculated Revolutions for a Surface Area of 1,800 sq. cm. per g.	Revolutions Saved by the Grinding Aid	Percentage of Revolutions Saved
Vinsol rosin	1,770	1,840	2,540	1,225	32.5
Cod oil	1,815	1,970	2,670	1,095	29.0
Beef tallow	1,750	2,025	2,725	1,040	27 6
Nopco 1900	1,795	2,110	2,810	955	25.4
Nopco Plastol No. 1	1,840	2,125	2,825	940	25.0
Kojic acid	1,828	2,140	2,840	925	24.6
Aluminum stearate	1,880	2,160	2,860	905	24.0
Blank (3.5 per cent. gypsum but no grinding aid)	1,821	3,065	3,765	000	00.0
Powdered aluminum	1,821	3,310	4,010	— 245	— 6.5
No gypsum and no grinding aid	1,780	3,500	4,200	— 435	—11.6

TABLE II.—PHYSICAL TESTS OF CEMENTS.

Grinding Aid	Normal Consistency (*percentage water by weight*)	Time of Set (*hours and minutes*)		Pat Soundness Test	Soundness Test in Autoclave (*percentage growth*)	Tensile Strength (*pd. per sq. in.*)	
		Initial	Final			At 7 days	At 28 days
No gypsum and no grinding aid	31.0	10:00	20:00+	Failed	[1]	335	383
Blank—3.5 per cent. gypsum but no grinding aid	23.5	2:40	5:00	O. K.	0.0970	433	497
Cod oil	27.0	2:50	6:00	O. K.	0.1555	382	453
Nopco 1900	25.5	3:10	5:00	O. K.	0.1045	392	445
Nopco Plastol No. 1	27.5	3:10	5:55	O. K.	0.1140	387	453
Beef tallow	27.5	3:00	6:00	O. K.	0.1240	397	463
Kojic acid	25.0	2:30	4:45	O. K.	0.1020	408	488
Metallic aluminum	23.5	2:45	5:45	O. K.	0.0910	320	390
Vinsol rosin	26.0	2:45	5:35	O. K.	0.1100	362	483
Aluminum stearate	25.0	2:30	5:15	O. K.	0.1205	407	525

[1] The set of the cement in the specified time was not sufficient to allow the beams to be removed from the molds intact and undamaged.

TABLE III.—DETAILS OF CONCRETE SPECIMENS, 1:4 MIX BY VOLUME.

Grinding Aid	Specific Surface of Cement (*sq. cm. per g.*)	W/C by Volume	Slump in Inches (*12-in. cone*)	Weight of Fresh Concrete (*pd. per cu. ft.*)	Average 28-day Compressive Strength of Each Four, 3-by 6-in. Cylinders (*pd. per sq. in.*)
Kojic acid	1,828	0.79	1.5	150	7,440
Aluminum stearate	1,880	0.83	1.3	152	6,540
Cod oil	1,815	0.80	1.4	148	6,330
Blank—3.5 per cent gypsum, but no grinding aid	1,821	0.78	1.6	152	6,050
Beef tallow	1,750	0.80	1.3	151	6,030
Nopco Plastol No. 1	1,840	0.80	1.5	150	5,390
Vinsol rosin	1,770	0.80	1.3	145	5,180
Nopco 1900	1,795	0.79	1.4	148	5,020
No gypsum and no grinding aid	1,780	0.92	1.5	148	4,170
Metallic aluminum	1,821	0.78	1.3	151[1] 139[2]	2,600

[1] 151 pounds per cubic foot was the weight immediately after mixing the mortar.
[2] 139 pounds per cubic foot was computed from the percentage of bulking at the end of 2½ hours.

best grinding aid from the standpoint of reducing mill revolutions with this particular clinker.

Table II shows the test results of the various cements. The various grinding aids exerted a considerable influence on all the properties measured. Only the aluminium stearate gave as high a 28-day strength as the blank, and none of the grinding aids gave as high a 7-day strength. Cement made with no gypsum and no grinding aid was unsound.

Concrete specimens were made from each of the cements to determine strength and durability. The strength specimens were 3-in. by 6-in. cylinders, while the durability specimens were 2-in. by 2-in. by 11¼-in. beams. The aggregate used was gravel with a maximum size of ¾ in. A straight-line gradation was used.

Table III shows the properties of the concrete mixes used. The grinding aids are listed here in the order of decreasing 28-day compressive strengths. The water-cement ratio required to produce approximately a 1½ in. slump varied somewhat with the various grinding aids. The weight per cubic foot also varied somewhat, and the 28-day compressive strength of the 3-in. by 6-in. cylinders varied considerably. A comparison of this table with Table I shows that the best grinding aid, Vinsol resin, did not produce the strongest concrete. Moreover, except for powdered aluminium, Vinsol resin produced concrete of the lowest density. Kojic acid, aluminium stearate, and cod oil definitely improved the strength. Beef tallow showed little effect, and the others decreased the strength.

The beams for the durability tests were fitted with a gauge plug in each end so that any change in length could be measured with a dial comparator. Past experience has shown that an increase in length is a measure of deterioration of concrete, especially in the freezing-and-thawing test. Recent experiments at Kansas State College have shown a simultaneous reduction in the sonic modulus of elasticity with the increase in length.

Twelve beams were made from each cement. Three of these were used as moist-room control specimens; three were subjected to alternate freezing and thawing; three to isothermal wetting and drying at 135 degrees F.; and three to alternate heating and cooling in water. The sonic modulus of elasticity was determined, using an oscillator to vibrate the beams and a pick-up to determine when the beam was vibrating in the fundamental mode. From the dimensions and density of the beams and the resonant frequency of vibration the sonic modulus of elasticity was computed. Changes in length and frequency were measured on all beams at regular intervals during the test. The results of these measurements were as follows:

The moist-room control specimens shrank an average of 0·0037 per cent. during the first week and then remained practically constant in length for over 21 weeks. There was no expansion; some did not shrink at all, while the largest shrinkage was 0·0075 per cent. During this time the sonic modulus of elasticity of the specimens gradually increased. For example, at 18 weeks the maximum increase was 15 per cent., and the minimum 11·5 per cent. The effect of the grinding aids on the length and the modulus of elasticity was practically nil for the moist-room control specimens.

The freezing-and-thawing tests produced the greatest effect of any of the tests. At 150 cycles the specimens containing beef tallow had expanded 0·13 per cent., and the modulus of elasticity had decreased by 41 per cent. These specimens exhibited the least resistance to freezing and thawing. Next in order came Nopco Plastol No. 1 with 0·08 per cent. expansion and 32 per cent. reduction in modulus. The powdered-aluminium specimens were next with 0·02 per cent. growth and 16 per cent. reduction. Cod oil came next with 0·005 per cent. expansion and 9 per cent. reduction in modulus. Specimens containing the other grinding aids showed practically no change in length (± 0·005 per cent.) and an average of 5 per cent. reduction in sonic modulus. At 400 cycles there was little change in these specimens. Specimens containing Vinsol resin were most resistant to freezing and thawing.

Isothermal wetting and drying was performed at the rate of one cycle per day at a uniform temperature of 135 deg. F. At 100 cycles all the specimens, except those containing powdered aluminium, had contracted about 0·02 per cent. The specimens containing powdered aluminium contracted only 0·005 per cent. The modulus of elasticity likewise showed little change except for the specimens containing powdered aluminium, which showed a decrease of 20 per cent. at 100 cycles. This test proved of little value as a durability test.

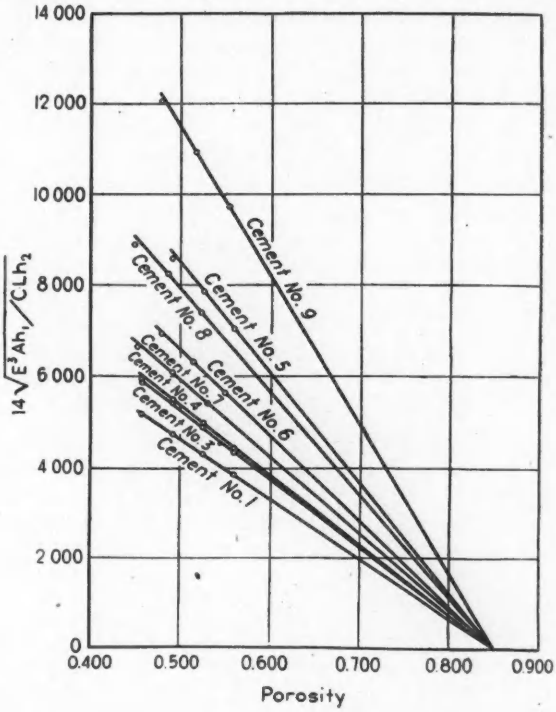
The heating-and-cooling test was conducted through a temperature range of 60 to 140 deg. F. Twenty-four complete cycles were obtained each day. The specimens were submerged in water during the entire test, and the temperature of this water was raised and lowered gradually, using steam and tap water. At 2,400 cycles the specimens containing the unsound cement had grown 0·025 per cent., with practically no change in the sonic modulus. The other specimens were grouped rather closely together so far as change in length was concerned, the range being from + 0·005 per cent. for cements with cod oil and Nopco 1900 to + 0·012 per cent. for specimens containing powdered aluminium. The modulus of elasticity showed a somewhat greater spread. Specimens containing beef tallow and kojic acid showed an increase of 8 per cent. The Nopco products showed an increase of 7 per cent., Vinsol resin and the blank 5 per cent., cod oil 2 per cent., and powdered aluminium 0 per cent.

One may conclude, within the limitation of these tests, as follows : Vinsol resin, cod oil, and beef tallow increased the efficiency in grinding. Aluminium stearate increased the tensile strength. Kojic acid, aluminium stearate, and cod oil increased the compressive strength. Vinsol resin increased the resistance to freezing and thawing. Nopco Plastol No. 1, Nopco 1900, and cod oil increased the resistance to heating and cooling.

These tests, while limited in scope, show that none of the grinding aids tested was ideal for all conditions in service. The grinding and durability tests were all performed within a year. After three years the durability may be radically different from that shown. It should be noted also that the results might be radically different if another clinker were used.

Determining the Fineness of Portland Cement.

TESTS have been made on eight different types of cement at twenty-two different laboratories in order to find the measure of agreement in the use of the air-permeability method of determining fineness. The tests were made under the direction of the American Society for Testing Materials. A report on the tests points out that it has been recognised that in the air-permeability method of determining fineness there are variations in specific surface value depending upon



the porosity of the compacted bed of material and possibly the rate of air flow. It has also been recognised that some cements are more difficult to compact than others. It was, therefore, considered necessary that further information be obtained about the air-permeability method of determining fineness before a comprehensive specification could be drawn up for its use for Portland cement and related material.

The purpose of the investigation was to determine: (1) The porosity to which the cements should be compacted; (2) the amount of variation of surface area values obtained by different laboratories both when using a constant pressure across the apparatus and by using a constant rate of flow through the apparatus;

(3) the "index of compaction" as proposed by the Bureau of Reclamation; and (4) the variations obtained by different operators when using a constant weight to compress the samples of cement.

The eight samples of cements were identified by number as follows: No. 1, Portland cement; No. 3, Moderate-heat Portland cement; No. 4, Portland cement with Vinsol resin interground; No. 5, High-early-strength Portland cement; No. 6, Portland-pozzolana cement; No. 7, Portland cement raw mix; No. 8, Masonry cement; No. 9, Masonry cement "waterproofed."

The following instructions were furnished to the co-operating laboratories: (*A*) A study of the variations of specific-surface values with porosity when using a constant pressure across the apparatus and the determination of the variations of results of different laboratories; (*B*) A study of the degree of compaction; (*C*) A study of variations of results of different laboratories when using the same rate of flow through the bed of powder; (*D*) a study of the variations of specific surface values obtained by different laboratories when using a constant weight to compress the samples of cement.

The samples were tested as received, without any drying or heat treatments. The testing procedure was as follows: (1) Weigh out the required amount of cement to 0·01 gr., and place in the permeability cell. (2) Tap the sides of the cell to consolidate and level the powder. (3) Insert plunger without turning and compress the cement slowly until the collar of the plunger is in contact with the top of the cell. (After this operation care must be taken not to jolt or jar the permeability cell.) (4) Turn the plunger one complete revolution, keeping the collar of the plunger in contact with the top of the cell. (5) Remove the plunger slowly and with a rotary motion. (6) Remove the cement from the sides of the cell and plunger and from the vent hole in the plunger and return this cement to the permeability cell. (7) Repeat 3, 4, 5, and 6. (8) Connect the permeability cell to the apparatus and start the flow of air. (Care must be taken to ensure a good seal between the cell and the apparatus.) (9) Record manometer readings when the levels of the liquids of manometers are in equilibrium—usually 3 to 5 minutes.

Fig. 1 shows that for the eight cements tested the differences in values shown by each of the cements are not significant. In supplementary work on other materials different values have been obtained for the constant.

Conclusions.

(1) There was better agreement between laboratories when cements were tested at a porosity at which an index of compaction of from 2·0 to 10·0 mm. was obtained than when tested at either higher or lower porosities.

(2) Agreement between laboratories was better when using a constant pressure across the apparatus than when using a constant rate of flow of ½ litre per hour with all samples. The specific surface values obtained when using the ½ litre per hour flow were very nearly the same as obtained when using a constant pressure across the apparatus.

(3) The index of compaction test showed promise of great usefulness in judging the proper degree of compaction. Variations in terms of percentage were large.

(4) The use of a 10-kg. compressive force to compact the cement resulted in less agreement between laboratories than was obtained by other methods. This was probably due to the difficulty of accurately determining the porosity.

There is a need for a standard sample to furnish a correction factor to compensate for errors in measurement and the personal equation in testing. A change in the Lea-Nurse formula has been proposed by which the values obtained for specific surface are more nearly the same, regardless of the porosity at which determined.

Determining the Clinker Content of Cement.

A METHOD of determining the clinker content of clinker-limestone base in masonry cement has been devised by Messrs. J. R. Ronig and V. E. Wessels, of the Missouri Portland Cement Co. The method is described in "Rock Products" for June, 1943, from which the following notes are taken. The method consists of making a CO_2 determination and an acid titration on the sample. It can be applied to all clinker-limestone-base cements which contain no large amounts of other chemically active constituents. The presence of chemically inert substances will not reduce the accuracy of the determination.

The CO_2 determination is made by means of an alkalimeter and an absorption train as illustrated in Fig. 1. The alkalimeter (A) consists of a reaction flask, a water condenser, an acid dropping funnel, and an Ascarite absorption tube for the removal of CO_2 from the incoming air. The drying tubes (B), (C) and (D) contain Drierite, anhydrous $CuSO_4$, and Drierite respectively for removal of water and HCl vapours from the gas stream. These tubes should be of sufficient size to ensure complete removal of the water and HCl vapours without too frequent changing of the drying reagents. The weighing bottle (E) contains Ascarite, with an upper layer of Drierite for removal of the water formed by the reaction between Ascarite and CO_2. After passing (E), the remaining gas (air only) passes through traps (F), (G), and (H), with (G) containing concentrated sulphuric acid. The gas flow is induced by means of a water pump, and controlled with a screw clamp.

The following special solutions are required for the determination: HCl (about 2·4 normal)—add 370 ml. of concentrated HCl to 1,700 ml. of distilled water. NaOH (about 1·2 normal)—dissolve 96 grams of NaOH pellets in 2,000 ml. of distilled water. 25 ml. of 2·4 normal HCl are used so that sufficient acid is present to dissolve the cement readily. After all the cement is dissolved, 25 ml. of 1·2 normal NaOH are added to nearly neutralise the excess acid present so that only a relatively small amount of 0·4 normal NaOH is required for the back titration. The normality of the resulting solution (25 ml. of 2·4 normal HCl plus 25 ml. of 1·2 normal NaOH) is determined and this solution is designated as the standard dissolving solution. 0·4N NaOH—Dissolve 32 gr. of NaOH pellets in 2,000 ml.

of distilled water and standardise to 3 decimal places with standard acid. Bromothymol blue : Methyl red indicator—Dissolve 0·025 gr. methyl red and 0·075 gr. bromothymol blue in 100 ml. of alcohol. Approaching neutrality from the acid side this indicator changes from red to yellow to blue-green at a *p*H of 6–7, thus allowing almost complete precipitation of R_2O_3 in the titration.

The determination is based on the ratio between the acid requirement of the clinker content and the total acid requirement of the cement if it were composed of 100 per cent. clinker. To obtain this ratio the following derivation is made in order to differentiate between the acid required for solution of the clinker and that required for the limestone.

A_t = ml. of standard dissolving solution required for the solution of 1 gr. of the cement.

A_c = ml. of standard dissolving solution to dissolve the clinker component of the 1 gr. sample.

A_l = ml. of standard dissolving solution to dissolve the limestone component of the 1 gr. sample.

Then $A_c = A_t - A_l$ .. .. (1)

and

$$A_t = B - \frac{nU}{N} \qquad (2)^*$$

$$A_l = \frac{2 \times 1{,}000G}{44.01N} = \frac{45.44G}{N} \qquad (3)\dagger$$

in which

B = total ml. of standard dissolving solution,

---

* The reactions taking place are as follows :

$SiO_2 \cdot H_2O + HCl$ (no reaction) .. .. (a)

$Fe_2O_3 + 6HCl = 3H_2O + 2FeCl_3 \longrightarrow {}^{+}6NaOH = 2Fe\,(OH)_3 + 6NaCl$ .. .. (b)

$Al_2O_3 + 6HCl = 3H_2O + 2AlCl_3 \longrightarrow {}^{+}6NaOH = 2Al\,(OH)_3 + 6NaCl$ .. .. (c)

$CaO + 2HCl = CaCl_2 + H_2O$ .. .. (d)

$MgO + 2HCl = MgCl_2 + H_2O$ .. .. (e)

$CaSO_4.2H_2O + HCl = Ca{+}{+}{-}{-}{+}SO_4 \longrightarrow {}^{+}HCl + 2H$ .. .. .. (f)

Since the R_2O_3 is precipitated as $R(OH)_3$ at the end point, only the CaO (less that in $CaSO_4.2H_2O$) and MgO contents [reactions (d) and (e)] control the acid requirement to the bromethymol blue-methyl red end point.

† The derivation of equation (3) is as follows :

G = moles CO_2 evolved from 1 gr. of cement.

44·01 = moles $CaCO_3 + MgCO_3$ from limestone.

As in the case of the clinker, CaO_3 and $MgCO_3$ control the acid requirements of the limestone constituent.

Since

$CaCO_3 + 2HCl = CaCl_2 + CO_2 + H_2O$ .. .. (g)

$MgCO_3 + 2HCl = MgCl_2 + CO_2 + H_2O$ .. .. (h)

Then

$$2 \times \frac{G}{44{\cdot}01} \times \frac{1000}{N} = \frac{45{\cdot}44G}{N} = A^1 \qquad (3)$$

N = normality of the standard dissolving solution,

U = ml. of standard NaOH used in back titration of the sample,

n = normality of standard NaOH (0·4 normal), and

G = net gain in weight in grammes of the Ascarite weighing bottle = gramme of CO_2 from 1 gr. of cement.

Now

$$\text{Per cent. clinker} = \frac{100Ac}{M} \qquad \text{(4)}$$

in which

M = ml. of standard dissolving solution required to dissolve 1 gr. of pure clinker.

Combining equations (1), (2), (3), and (4),

$$\text{Per cent. clinker} = 100\frac{BN - nU - 45.44G}{MN} \qquad \text{(5)}$$

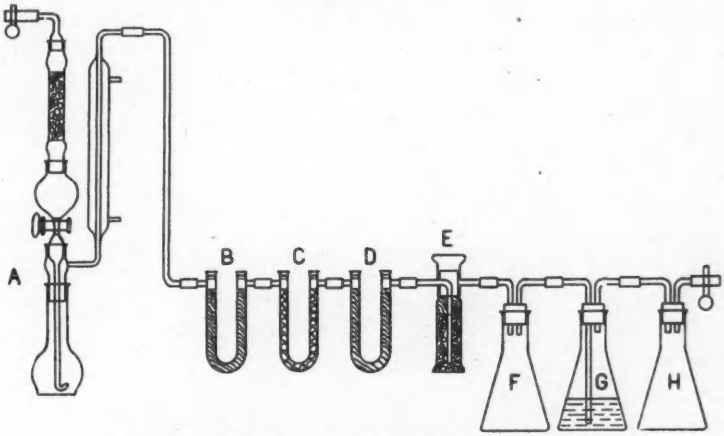


Fig. 1.—Apparatus for Determining CO_2 Content.

But

$$MN = 1{,}000W \qquad \text{(6)}$$

in which .

W = moles of HCl required to dissolve 1 gr. of pure clinker.

Therefore, combining (5) and (6),

$$\text{per cent. clinker} = \frac{BN - nU - 45\cdot44G}{10\,W} \quad \ldots \quad (7)$$

All terms in the numerator of equation (6) are determined by direct analysis of the cement. W is calculated from the average of several chemical analyses of the clinker being used; it is equal to twice the sum of the number of moles of CaO (minus moles SO_3) plus the moles of MgO contained in 1 gr. of the clinker. It has been found that deviations from this average of W are so slight for any given type of clinker that its use as a constant in equation (7) gives results which are well within the experimental error of the method.

Results.

The results of several determinations on experimentally prepared cements in which the clinker and limestone contents were known are shown in Table I.

TABLE I

Per cent. clinker

Actual	Determined	Difference
35·8	34·8	−1·0
44·5	43·3	−1·2
47·7	45·8	−1·9
47·7	48·0	+0·3
47·8	46·2	−1·6
47·8	46·5	−1·3
47·9	47·0	−0·9
48·0	46·8	−1·2
48·0	50·0	+2·0
48·0	49·5	+1·5
50·0	51·1	+1·1
50·4	51·3	+0·9
50·4	51·5	+1·1
50·4	50·0	−0·4
51·9	52·2	+0·3
51·9	52·0	+0·1
59·7	58·5	−1·2
59·9	57·9	−2·0
70·2	69·8	−0·4

Although the data were limited, the probable error of the method was calculated and found to be $\pm0\cdot9$ in the percentage of clinker actually present. This is probably a conservative figure since some of these determinations were made before the analytical procedure was entirely standardised.

Procedure.

When the train is airtight a blank determination should be made as follows: Aspirate a current of air through the system for ten minutes, after which remove the absorption bottle and weigh. Reconnect the absorption bottle and put 25 ml. of HCl ($2\cdot4N$) into the dropping funnel. Remove the aspirator tube and slowly

introduce the acid into the reaction flask so that 2 to 3 bubbles per second of gas pass through the H_2SO_4 trap. Close the dropping funnel stopcock and bring the solution to a boil, while adding 25 ml. of NaOH (1·2N) to the funnel. When the solution boils, remove the heat source and carefully allow the NaOH to enter the reaction flask. (The combined additions of HCl and NaOH are equivalent to a 50 ml. addition of about 0·6N HCl, known as the dissolving solution, and the standardisation is made on this basis.) Draw air through the apparatus for 30 minutes at a rate of 2 to 3 bubbles per second. Remove and reweigh the absorption bottle, designating the gain in weight as (g). Using distilled water, thoroughly wash down the insides of the dropping funnel and water condenser into the reaction flask. Titrate the contents of the flask with standard 0·4N NaOH to the bromothymol blue-methyl red end point. Compute N, the normality of the dissolving solution, to the third decimal place as follows :

$$N = \frac{nV}{50}$$

in which V = ml. of standard 0·4 normal NaOH used in back titration of the blank and n = normality of standard NaOH to 3 decimal places. N and (g) should be taken as the average of at least three determinations.

Sweep the system for ten minutes and weigh the absorption bottle. Weigh a 1-gr. sample of cement and introduce it into the dry reaction flask. Pipette 26 ml. of the 2·4 normal HCl solution into the dropping funnel, and begin to drop the acid slowly into the reaction flask. Care must be taken not to pass the CO_2 too rapidly through the weighing bottle. Continue as outlined in the blank procedure. Determine the gain in weight of the absorption bottle, and subtract (g), the average gain in weight found in the blank determinations. The corrected figure G is the net weight of CO_2 evolved from the sample. Titrate the contents of the reaction flask with standard NaOH (0·4N) to determine U. Use the following form of equation (7) to calculate the percentage of clinker present.

$$\text{Per cent. clinker} = \frac{50N - nU - 45{\cdot}44G}{10W} \qquad \text{(7a)}$$

in which

N = normality of the standard dissolving solution,
n = normality of the standard 0·4 normal NaOH,
U = ml. of standard NaOH used in back titration of the sample,
G = grams of CO_2 evolved from the 1-gr. of cement, and
W = moles of HCl required to dissolve 1 gr. of pure clinker.

Grinding Hard Nibs by the Centrifuge Process.

SOME information is now available of the results of installing a centrifuge in closed circuit with tube mills with the object of reducing difficulty experienced in grinding raw material of variable hardness. The plant in question, belonging to the Lone Star Cement Corporation, is situated at Houston, Texas, and oyster shells comprised the raw calcareous material. Most of the shell grinds readily, but the portion making the hinge is very tough. With normal grinding

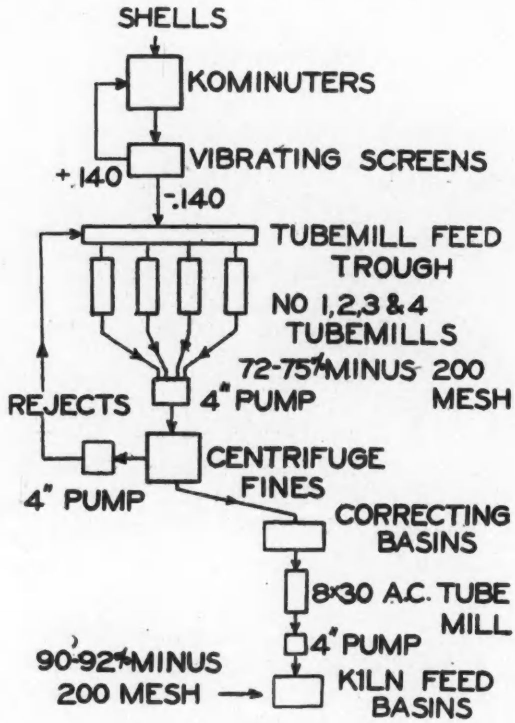


Fig. 1

its inclusion in the raw mix results in large flat particles, and in order to reduce this to a size suitable for cement burning these tough pieces have to be worn down. In open circuit grinding this results in excessive fineness of the major part of the slurry with a corresponding increase in power requirements and reduced output. A centrifuge was installed in February, 1941, and after some minor changes in the design of the machine and the general arrangement it accomplished the desired result and has become a part of the raw mill equipment.

Before the centrifuge was installed the shells first went to Kominuters, which operated in closed-circuit with a battery of vibrating screens. At first screens having an opening of 0·05 in. were used. This gave low capacities so the openings were enlarged to 0·10 in. At this point the centrifuge was installed farther along in the system, so that while the Kominuters are still used it was possible to enlarge the screen openings again to 0·125 in., with a large increase in mill capacity. Still later 0·140 in. screens were installed and again the capacity was increased.

The flow sheet (*Fig.* 1) indicates the use of the centrifuge. The minus 0·140 in. material, which is the entire raw mill flow, goes to four tube mills, which deliver to the centrifuge by means of a 4 in. pump driven by a motor through V-belts. The centrifuge makes two products, namely fines and rejects; the rejects consist of the coarse portion of "nibs," which is roughly 8 to 10 per cent.

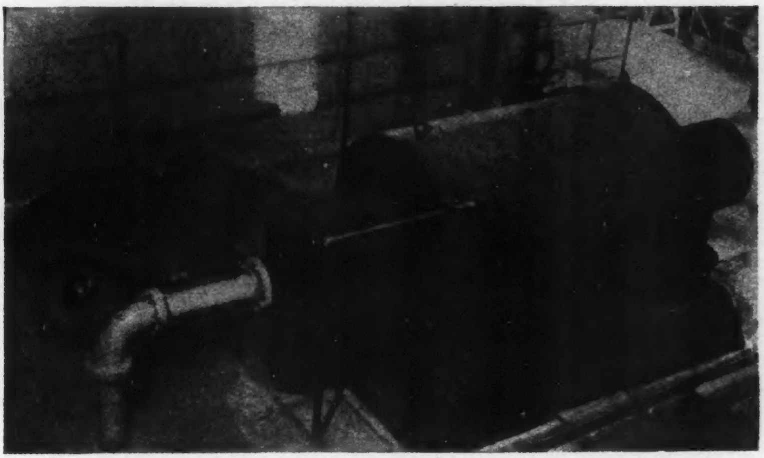


Fig. 2.

of the total passed through the machine. Actually only 3 to 4 per cent. is coarser oversize, but the included fines rejected by the machine make up the totals indicated. The rejects are pumped back to the tube-mill feed-trough and then passed through the tube mill for further grinding. The fines go to correcting basins, where they are analysed and mixed. They then go through an 8 ft. by 30 ft. tube mill, and the finished slurry is pumped into the kiln-feed basins.

About a year ago a fourth tube mill was installed. This addition, plus the increased capacity of the centrifuge, brought the capacity of the mills up to 333,000 tons a year. Thus more than 1,000 tons of raw mix are screened per day. The centrifuge measures 54 in. by 70 in., and is driven by a 100 h.p. motor through a rope drive.

The centrifuge (*Fig.* 2) has been in practically continuous operation since May, 1941, and for the past year it has been in continuous service without overhaul. Wear in the machine is confined to the inner cone or conveyor; the port

holes through the inner shell become elongated, so a spare conveyor is kept on hand. These parts and other surfaces subjected to heavy wear are built up with hard surfacing welding. The speed of the outer cone is kept at 400 r.p.m. and the inner cone at 393 r.p.m. These speeds are controlled through a planetary gear unit in conjunction with a variable-speed motor.

Some Notes on Selecting Motors.

IN selecting a motor for any particular drive, the first essential is to determine what type of motor will work successfully under the conditions to be met. Apart from considerations of horse-power and speed, to work successfully a motor must start and accelerate under the load it will have to carry, as well as any reasonable overload, and also be capable of bearing its normal load without incurring a temperature rise which would lead to deterioration of the windings.

The primary considerations are: (*a*)the kind of machinery to be driven; (*b*) the starting load; (*c*) speed and speed variation; (*d*) local conditions. The first three items are largely interconnected, and knowledge of the machine to be driven decides the likely starting load and speed. Two important factors in connection with any power drive are torque and speed. That it will carry its normal load, if necessary under continuous running conditions, is practically assured if the machine complies with British Standard Specifications. The chief risk lies in under-estimating the load and selecting a motor on the small side, which becomes overheated, with consequent insulation and other troubles. On the other hand, considerable loss of efficiency results if much too large a motor is used and run at only half load.

Direct-current motors can be divided into three main classes, namely: (1) series wound; (2) shunt wound; and (3) compound wound. The series motor gives good speed variation with load, and is therefore useful for heavy loads which may have to be handled at a lower speed than light loads. The shunt motor runs at constant speed for all loads, but is not suitable for starting up against a heavy load. These considerations have led to the compound-wound motor, which provides speed variation in addition to the capability of starting up against a heavy load.

Alternating-current motors may also be divided into three main types, namely: (1) induction motors (squirrel-cage or slip-ring); (2) synchronous motors; and (3) commutating motors. The first is a constant speed machine (the speed does not vary much more than 4 per cent. between full load and no load), and a starting torque equivalent to about three times the full-load torque can be obtained. In cases where the starting load is heavy a centrifugal clutch provides a simple means of dealing with it, and in practice this often proves better than certain types of starting gear specially designed to increase the starting torque of the motor. The squirrel-cage induction motor is a simple machine and has no commutator, so that brush gear and commutator troubles are absent. The slip-ring type of induction motor, like the squirrel-cage machine, has the characteristics of high starting torque with the added advantage that the current

taken during acceleration can be limited ; this is the type generally adopted where a large motor is required. For driving pumps, compressors, fans, motor generators, and machines where load and speed are constant, the synchronous type of A.C. motor is mostly used. The speed is fixed and unalterable ; in some cases this is a disadvantage, but this type of motor possesses a certain advantage in improving power factor. The induction motor, on the other hand, has a poor power factor. Where speed variation is required together with high efficiency and good starting torque, the commutating type of motor is usually selected ; these machines are more costly than either of the other two types.

In ordinary circumstances the " protected " type of machine is suitable, but in damp situations, or where fumes or dust are present, it will be worth while selecting a totally-enclosed machine. In cases where the motor operates a machine in the open, a weatherproof machine should be selected. Where inflammable or explosive gases or fumes are met with, a flame-proof and explosion-proof motor, together with control gear of a similar type, must be used. The greater the protection required in the outer covering the higher the cost. In the ordinary open-type motor the air helps to keep the armature and field windings cool ; the more the motor is enclosed the less the ventilation that can be arranged for, and consequently the larger the machine becomes and the more liberal has to be the allowance of copper in the windings to ensure that no undue temperature rise shall occur. The weight of metal involved in an enclosed ventilated type

motor is only about half that required for a totally-enclosed flame-proof and explosion-proof machine. Dust can have a very harmful effect on the motor, and in dusty and dirty surroundings it is well to have an enclosed ventilated machine.

Electrical machinery is so standardised that a practically direct relation exists between the price and the weight of copper and iron in a machine. Given two machines of similar type, horse-power, etc., if one is quoted at a much lower price than the other, then it is probable that the armature and field windings have been reduced in the cheaper machine. Provided that the horse-power required has been estimated on the safe side, the choice of the cheapest machine may be sound, but should the motor be required to deal with overloads for any considerable time troubles may ensue. Users of electric motors are sometimes unduly influenced by the price factor, and do not give sufficient thought to conditions of working and the selection of the right motor for the drive under consideration.

In the case of fans and compressors the motor should be capable of developing a large starting torque, and therefore have a rated size above that which would be normally required for the load under running conditions. A ram-type pump requires a constant-speed motor. A centrifugal pump, however, can have its capacity controlled by fitting a variable-speed motor, reducing the speed to lower the pump capacity, or it may have a constant-speed motor and its capacity be controlled by a throttle valve on the discharge side of the pump; the latter method is very general, as a variable-speed motor costs considerably more than a constant-speed motor. If constant pumping capacity at a given head is required, a constant-speed motor can be used, but it should be liberally rated, because if the head be decreased the motor is liable to be seriously overloaded. It is best, therefore, to select a motor of a size sufficient for operation with the minimum head that is likely to be called for.

A direct drive provides the most robust installation, but unfortunately in practice there is a limitation to the simplicity of the drive because slow-speed motors are very much more costly than those of high speed. If gear or belt drives are used for reducing speed then the higher the speed the better, subject to belt or gear speed limitations. In the case of A.C. motors the higher-speed machines have a much better power factor. D.C. machines can be designed to operate at any reasonable speed. The useful life of a motor should be from fifteen to twenty years, given regular oiling, cleaning, varnishing, painting, renewing bearings, etc. Good bearings and good design and workmanship are very desirable, for a slight difference in first cost is negligible when spread over the useful life of the motor.